1/20/81

INTERNAL LETTER

KING

Date:	January 20, 1981	**No:**	SFR/81-4
TO:	Gary Burrell	**FROM:**	Steve Russell
Loc/Dept:	MD-22	**Loc/Dept:**	MD-45
CC:	Jerry Schmitt MD 41	**Phone:**	2505

Subject: Suggestions for GPS Effort

1. Program Schedule

   A program schedule for the low-cost GPS design needs to be developed. It should give reasonable planning for 3½ years and detailed planning for the next 1½ years. Incorporate as much present NAVSTAR Program Info as is practical. This schedule will be needed to manage resources and coordinate the timing-critical tasks.

2. Cost and Manpower

   In conjunction with program scheduling, do cost and manpower planning for 3½ years. Do detailed manpower scheduling for first 1½ years and propose an approach to obtaining the manning level (12 engineers) needed by mid-1982. Cost information phased with the program schedule will help management track the program.

3. System Design Approach

   Develop a system design plan that will coordinate design efforts and identify critical functions. Try to identify desired levels of effort and schedule manpower.

4. Tradeoff Studies

   Do trade studies on critical functions. Look at as many system design alternatives as practical. Write up studies and outline design alternatives for management review. These studies will form the backbone of information to select the baseline system for development. Some suggested topics are: Antenna, Frequency Standard, Correlator, Non-Volatile RAM, Low-Power Time Source, Frequency Plan, VCO Design, CPU Selction, PVT interface, loss-of-lock detection, and data demodulation.

5. Market Analysis

   Collect available literature on civil market and do a summary and analysis to determine market areas and their potential as well as general customer needs. This market ID will aid the system concept development in engineering and provide a rational for the selection of customer-dependent design alternatives.

6. Orientation Meetings

Conduct a series of short (1-2 hrs) meetings to present the overall system concepts to team members. These would be held every 1 or 2 days until the essential topics are covered. The purpose of these "fireside chats" is to give all team members a basic understanding of the total system and an appreciation of each function and its attendant design problems.

7. NAVSTAR Program Schedule

Develop the best KRC concept of the NAVSTAR program schedule and keep it as current as possible. This will aid in the planning and management of the low-cost design schedule. This task should also track issues of congressional and Pentagon funding and civil availability and keep up with launch schedules.

8. NAVSTAR Program Contracts

Develop a list of military and contract people that can serve as contacts to obtain the latest info on NAVSTAR Program activities. We need this kind of effort to keep us well informed and to avoid committment of resources too early or too late.

9. Report to Management

Initiate and periodically update a summary report on the low-cost GPS program status. The key system issues should be covered as well as specific functional areas that have unique problems. This series of reports will serve as a "track and monitor" document.

10. Funding and Competition Profile

Determine key competitors and their progress on a civil GPS set. Compile a list of funding agencies and pursue the possibility of obtaining a contract. An "intelligence file" on competition and money sources should be established and kept current.

11. GPS Literature File

At the present time, an extensive file of literature on GPS is being maintained in the KRC library. This activity should continue with the goal of making the file as complete as possible.

A second file should be started and maintained by the GPS team. This file would contain only the "best" or "key" articles and would be organized along subject lines such as: program schedule, navigation algorithms, receiver design, antenna, ... etc. A numbering system should be established to give an easy method of reference. A topic cross reference of key GPS topics should be established which relates topics to papers covering those topics.

12. Denial of Accuracy

Determine the present status of denial-of-accuracy (DOA) implementation and find out if it is possible for KRC to participate in the ongoing discussions.

13. NISA Systems Committee

Continue to try and place a KRC person on Brad Parkinson's committee. He wants someone from our industry and I think we have a reasonable chance.

14. GPS Memo Library

Implement a technique of filing and numbering internally generated GPS design information. This will aid in adequately documenting designs and design progress. It will also serve as an easily accessable information source for new team members. The shear magnitude of design information that will be generated will soon overwhelm a casual approach to documentation.

SFR/csf

Steve Russell

2/6/81

LOW-COST GPS USER EQUIPMENT

System Analysis and Design Concepts

OUTLINE

6 FEB 1981

SUMMARY

7.0 PSU DESIGN

8.0 SIZE AND POWER ESTIMATES

9.0 PROJECT MANAGEMENT
- 9.1 Approach to Design
- 9.2 Design and Development Schedule
- 9.3 Development Cost (Non-Recurring)
- 9.4 Production Cost (recurring)
- 9.5 Market Analysis
- 9.6 NAVSTAR Program Schedule
- 9.7 Competition and Funding Sources

APPENDIX I. NAVSTAR SYSTEM OVERVIEW

1. Program
2. Satellites
3. Ground Control
4. User Equipment
5. Requirements

APPENDIX II. SATELLITE CHARACTERISTICS

1. Signal Generation
2. Data Formats
3. Orbital Characteristics

APPENDIX III. ANTENNA AND SIGNAL MODELS

Signal Levels C/N_0, J/S, G/T
SNR, NF, EW

APPENDIX IV. INITIAL ACQUISITION ANALYSIS

APPENDIX V. CORRELATOR DESIGN
APPENDIX VI. SYSTEM ANALYSIS
APPENDIX VII. TRADE-OFF STUDIES

APPENDIX VIII. DETECTION AND DEMODULATION THEORY

1.0 Introduction
2.0 Predetection Signal and Noise Models
3.0 Detection and Demodulation Concepts
4.0 Detector and Demodulator Analysis
5.0 Statistical Detection Theory

APPENDIX IX. LISTING OF GPS FUNDING AGENCIES AND COMPETITION

APPENDIX X. GPS ACRONYM AND ABBREVIATION DICTIONARY

APPENDIX XI. REFERENCES

APPENDIX XII. Bibliography

APPENDIX NAVSTAR SPECIFICATIONS

LOW - COST
GPS USER EQUIPMENT

System Analysis

and

Design Concepts

5 Feb 93

SUMMARY

1.0 INTRODUCTION

1.1 UE Functional Requirements

1.2 LRU Concept

1.3 UE System Concept

1.4 PVT Sensor Concept

1.5 CDU/NAV Concept

1.6 Power System Concept

1.7 Flight Performance Characteristics

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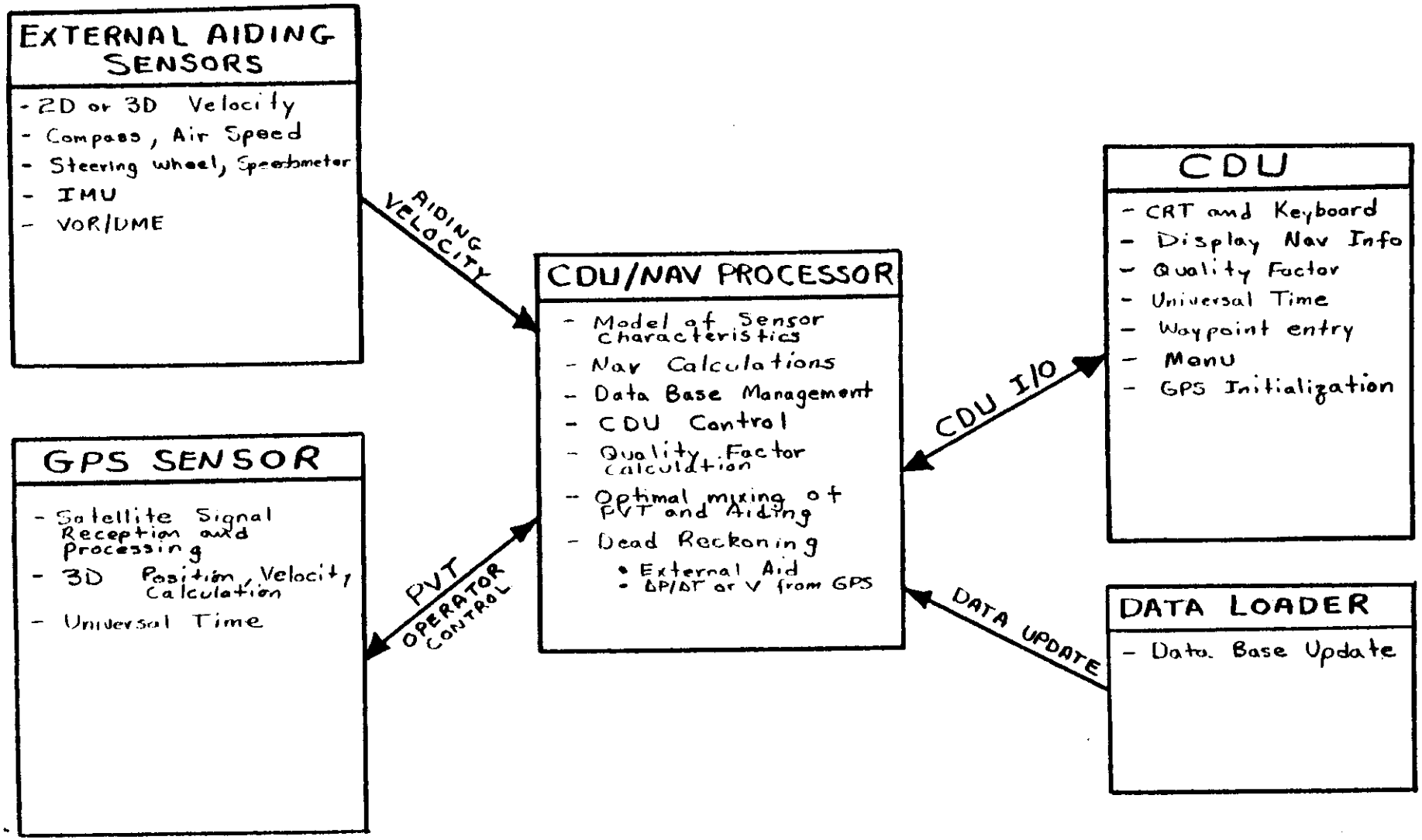
LOW-COST GPS DESIGN



FUNDAMENTAL SYSTEM CONCEPT

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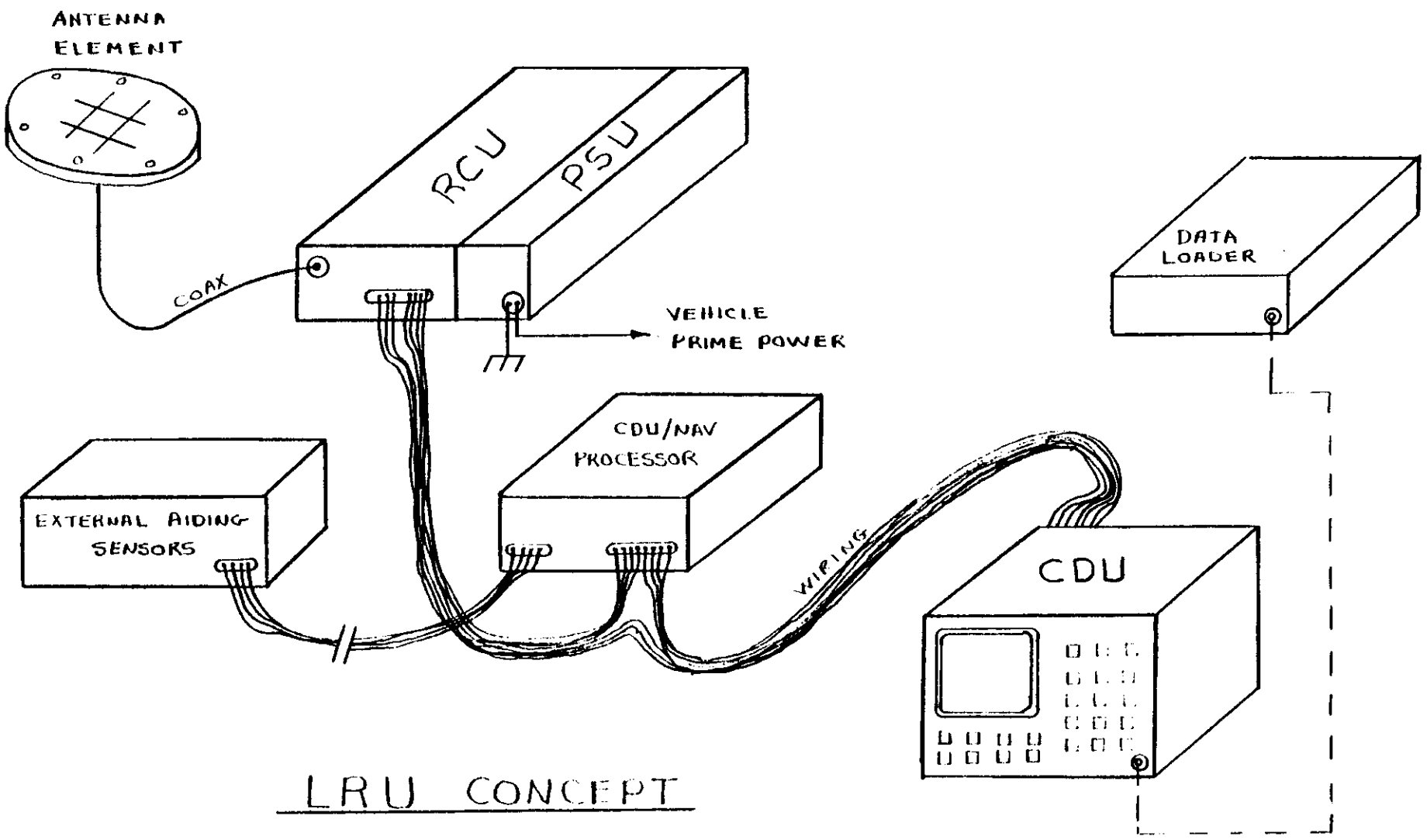
Table 1.1-1 UE Functional Requirements

Signal Reception	Navigation Calculations
Initial Acquisition	Data Base Management
Code Tracking	Operator Display
Carrier Tracking	Operator Control
Data Demodulation	Sensible Flight Performance
Loss-of-Lock Detection	Satellite Selection & Management
SNR Estimation	Dead Reckoning
Signal Reacquisition	
Pseudorange (Time Delay) Measurement	
PVT Calculations	External Aiding
Low-Power Time Keeping	Prime Power Conditioning

LOW-COST GPS DESIGN



LRU CONCEPT

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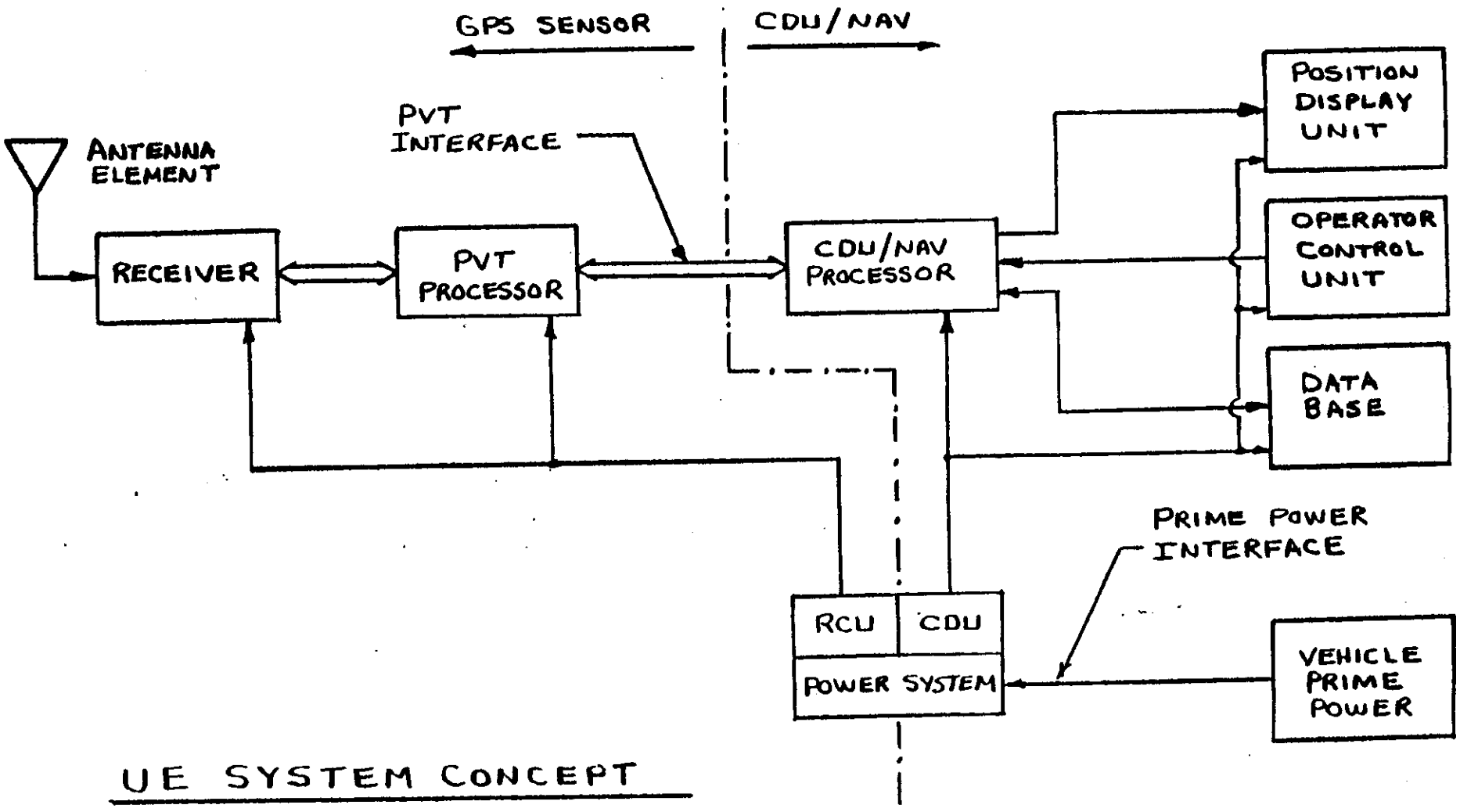

UE SYSTEM CONCEPT

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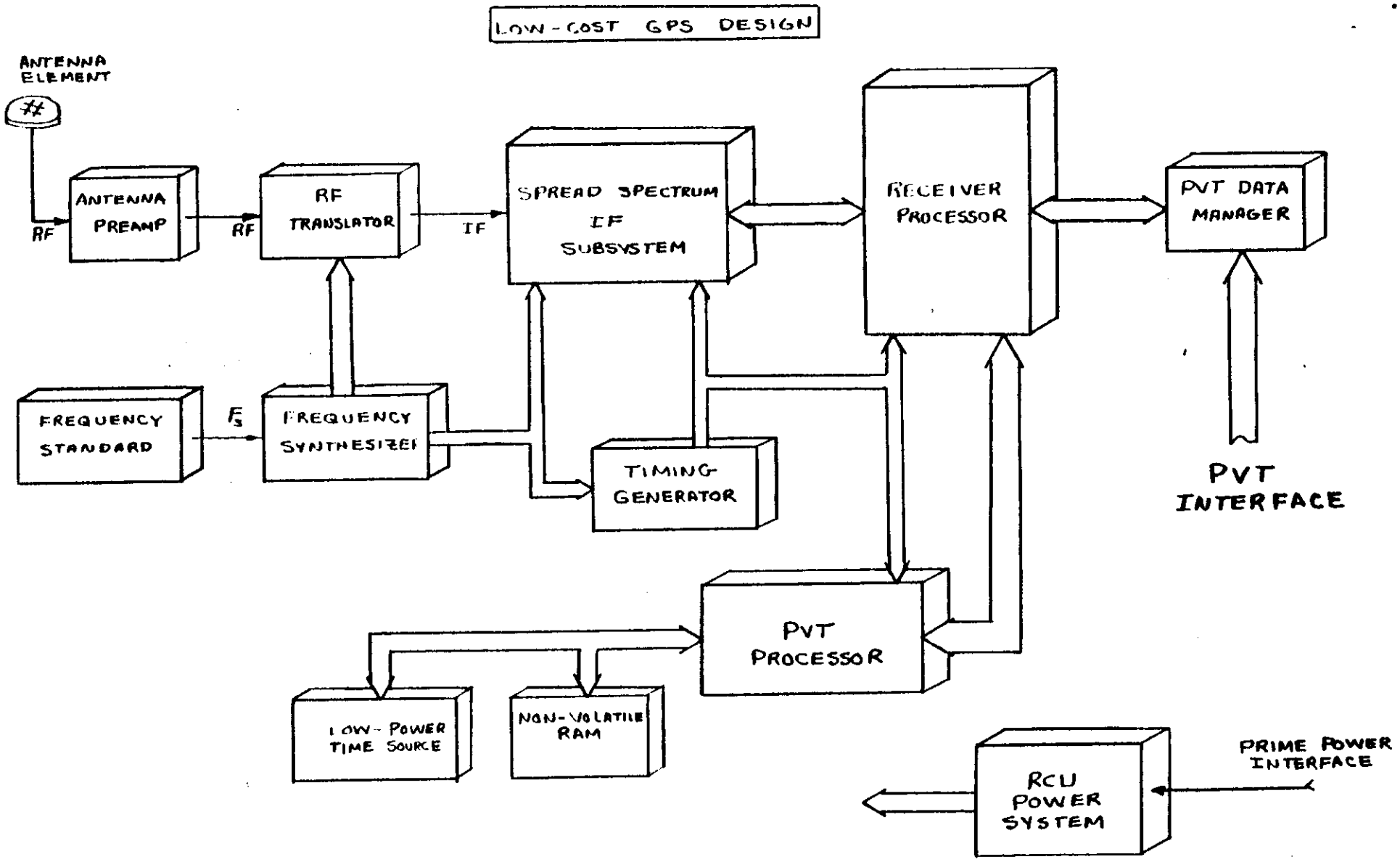

PVT SENSOR CONCEPT

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2.0 System Design

2.1 Requirements of the system

2.1.1 Hardware

2.1.2 Software

2.1.3 functional

2.2 Assumptions

2.2.1 Process L1 Signal only

- No dual-Frequency antenna or preselecter
- No L1/L2 ionospheric correction (a fixed algorithm is used)
- Simplified frequency plan

2.2.2 C/A Code Tracking only

- No complex hardware circuits required to slew precision code.
- Narrow band IF compared to military set

2.2.3 No Hostile Jamming

- Prompt channel may not be required
- Tau-dither tracking can be used to reduce hardware complexity
- No T-Code required
- No pulse jamming
- In-line correlator design is possible using only one code multiplier.

2.2.4 Top Mounted Antenna

2.2.5 Denial of Accuracy

- what is effect?

2.3 Analysis of Performance and Functions

2.3.1 Initial Acquisition

- Cold Start
- Normal Start
- Reaction Time
- False Acquisition
- Statistics and SNR performance

2.3.2 Frequency plan

2.3.3 SNR Analysis

2.3.4 Loss-of-Lock Detection

2.3.5 Doppler Analysis

2.3.6 Carrier tracking loop
- costas Loop - Arctan detector

2.3.7 Code tracking loop
- delay-lock Loop, sequential track

2.3.8 Data demodulation

2.3.9 Bit error rate

2.3.10 Position error

2.3.11 Power cycling
2.3.12 Critical Data
2.3.13 Fail-Safe Power

2.4 Flight Performance Characteristics

2.4.1 Maneuver Induced effects

- smoothness & display stability
- Satellite loss
- Satellite selection (SNR & DOP dependent)

2.4.2 Aiding

- Compass
- altimeter

2.4.3 Reduced Accuracy

- 3D, 3 satellite plus clock or altitude
- 3D, 2 satellite plus clock and altitude
- 2D, 2 satellite plus altitude
- 2D, 1 satellite plus clock and altitude

2.5 Hardware System Design

2.5.1 Correlator Design

- analog or digital?

2.5.2 Semicustom LSI

2.5.3 Frequency Standard

- Temperature
- Vibration
- Phase noise

2.5.4 Frequency Synthesizer

- Complexity
- Additive phase noise

2.5.5 Antenna Design

active or passive?

2.5.6 NCO Design

- rate multiplier
- VCXO

2.5.7 Processor Hardware

- Receiver
- CDU/Nav
- PVT
- analyze options and don't make selection too early

2.6 Software System Design

2.6.1 Software development planning

- HLL
- Structured
- 16 bit MDS
- Host simulation
- transfer to target

2.6.2 Receiver Software

- RCVR Management (Mode Structure,
- RCVR CHAN opr status
- Tracking loops
- Initial acquisition
- Time delay determination
- SNR estimation

2.6.3 PVT Software

- Executive design
- PVT calculation and algorithms
- Time calculation (LPTS)
- Pseudorange
- Satellite selection and management
- dead reckoning
- GDOP selection

2.6.4 CDU/Nav Software

- Nav algorithms
- Data base management
- Display output
- Operator control and interfaces

2.6.5 Processor Self-Test

- Health status on turn-on
- Periodic checking

3.0 Antenna Design

4.0 RCU Design

4.1 Hardware
4.2 Software

5.0 CDU/NAV Processor Design

5.1 Hardware
5.2 Software
- Sensor Modeling
- Nav Algorithms
- Data Base Management
- CDU Control

6.0 CDU Design

6.1 Hardware
- CRT
- Keyboard
- Keyboard Scan
- HV Power Supply
- Character Generator

6.2 Software
- Keyboard Processing
- Display Management

6.3 Human Factors
- Keyboard
- Display
- Operation

7.0 PSU Design

8.0 Size and Power Estimates

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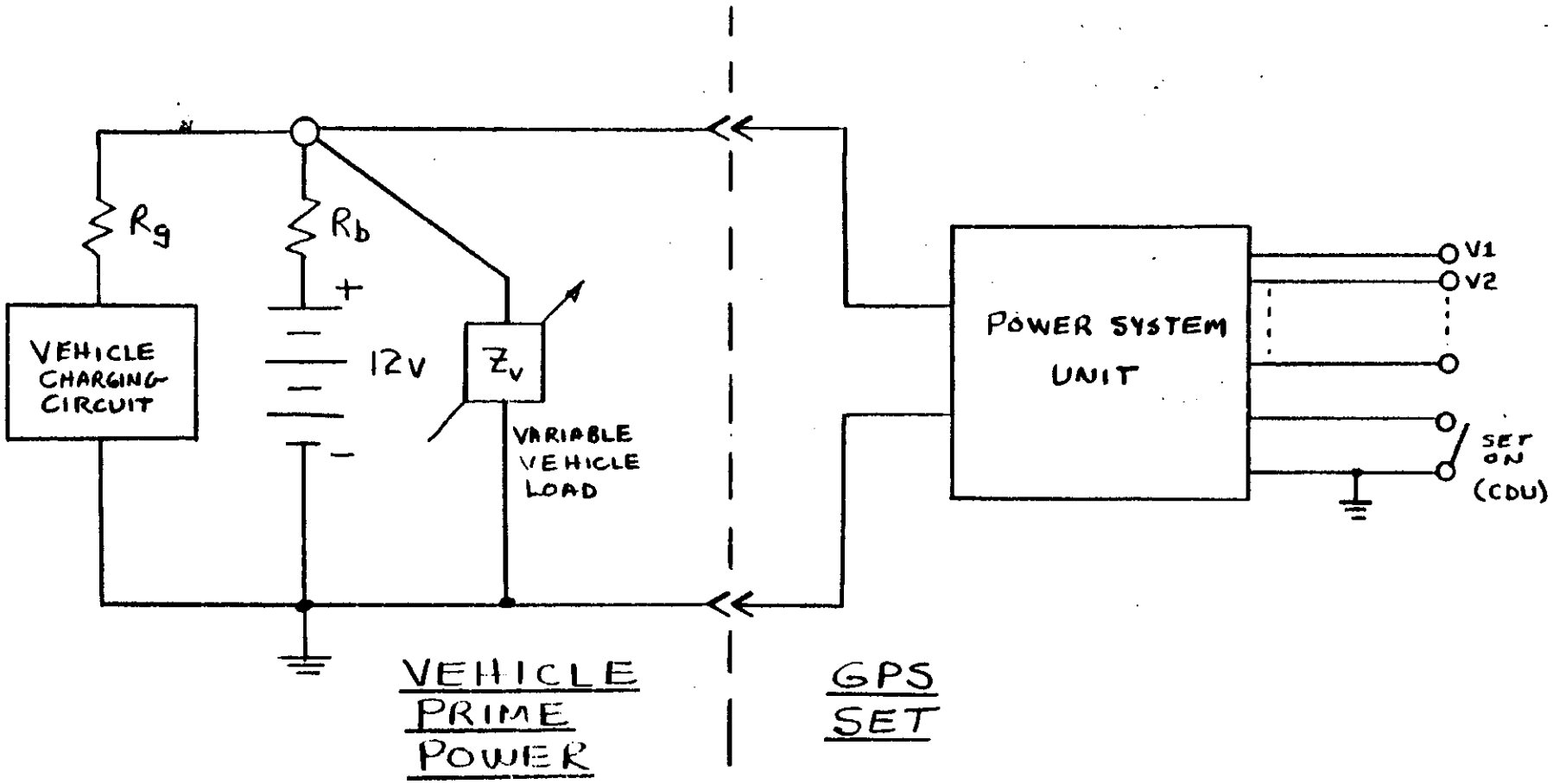
R_g
R_b
+
12V
−
Z_v
VARIABLE VEHICLE LOAD
VEHICLE CHARGING CIRCUIT
POWER SYSTEM UNIT
V1
V2
SET ON (CDU)
VEHICLE PRIME POWER
GPS SET

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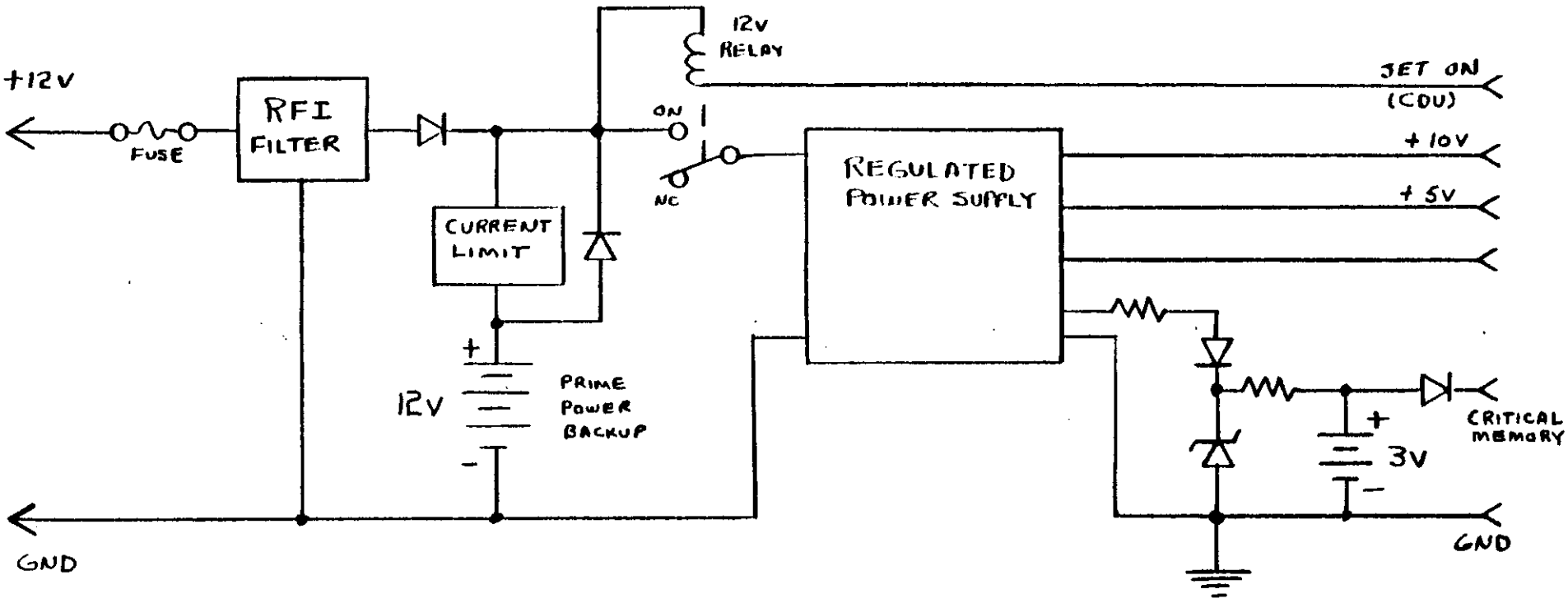
LOW-COST GPS DESIGN



POWER SYSTEM UNIT

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9.0 Project Management

9.1 Approach to Design

- Detailed system analysis
- Low-cost trade-offs
- Critical circuit testing
- Breadboard model development
- Engineering model development

9.2 Design and Development Schedule

- Phased to NAVSTAR program schedule
- Manpower requirements
- Technology risk

9.3 Development Cost (non-recurring)

9.4 Production Cost (recurring)

9.5 Market Analysis

9.6 NAVSTAR Program Schedule

9.7 Competition and Funding Sources

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Appendix I. NAVSTAR SYSTEM OVERVIEW

1. Program

2. Satellites

3. Ground Control

4. User Equipment

5. Requirements

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Appendix II. SATELLITE SIGNAL CHARACTERISTICS

1. Signal Generation

2. Data Formats

3. Orbital Characteristics

Appendix III. ANTENNA AND SIGNAL MODELS

Signal Levels
C/N_0, J/S, G/T
SNR, NF, BW

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Appendix IV. Initial Acquisition Analysis

Appendix V. Correlator Design

Appendix VI SYSTEM ANALYSIS

Bandpass Limiters
SNR Estimator
Phase-Locked Loop
Delay-Locked Loop
Pseudo-random noise model
DSSS Ranging theory for GPS
Bit and Word error rates
Generalized Costas Demodulator
In-Line Correlator Theory for DSSS
Runing Integrators
Frequency Standard Analysis

Appendix VII. TRADE-OFF STUDIES

- Antenna
- Frequency Standard
- Correlator
- Low-power Time Source
- Frequency Plan
- NCO Design
- Loss-of-Lock Detection
- Data Demodulation
- Non-volatile RAM
- PVT Interface
- Nav Algorithms
- Code Position / Doppler search strategies
- Processor Selection (SFR/80-4)
- Hold-up Power
- External Aiding
- Log / Linear IF
- Interference Susceptibility
- Frequency Synthesizer Design
- Human Factors
    - CDU display features
    - Keyboard
- Tracking Error Analysis
    - vs # of satellites (smoothing)
    - Type of filter
    - dead reckoning

Appendix VIII Detection and Demodulation Theory

1.0 Introduction

2.0 Predetection Signal and Noise Models

3.0 Detection and Demodulation Concepts

4.0 Detector and Demodulator Arrays

5.0 Statistical Detection Theory

1.0 Introduction